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Interactive comment on "Sensitivity of remotely-sensed trace gas concentrations to polarisation" *by* D. M. O'Brien et al.

Anonymous Referee #2

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The manuscript titled "Sensitivity of remotely-sensed trace gas concentrations to polarization" by O'Brien et al. describes the polarization dependence of a high resolution greenhouse gas spectrometer deployed in geostationary orbit. They find that, for the range of illumination and observation angles, and degrees of polarization expected of land surfaces in Asia and Australia, a polarized instrument introduces little additional error, when compared to an instrument with a "perfect" polarization scrambler. This is a good paper that is appropriate for publication in AMT. However it could be improved with some small editorial changes, highlighted below.

Introduction:

P2, Line 51: "The polarisation sensitivity of the geoCARB spectrometers imposes

strong, wavelength dependent signatures upon the spectra, which potentially could cause unacceptably large errors in retrieved concentrations of CO2, CH4 and CO. "

This statement is poorly supported in the rest of the paper. The spectrally-dependent variations shown in Figure 4 are smoothly varying, and not obviously correlated with CO2, CH4, and CO absorption features. Any model that fits for the slope of the continuum (as an albedo slope or radiance scaling) should be adequately compensate for such features. Features more strongly correlated with the spectral structure of the absorption bands (like those associated with Rayleigh scattering in the A-band) would produce much more serious errors, but no such errors are shown here.

Section 2:

I only spot checked the equations in Sections 2 and 3. It appears to be consistent with those in O'Brien et al. (2013).

Section 3:

Pg 6, Line 49: "Stokes vector after reflection from the north-south mirror will be" Try "The Stokes vector after reflection from the north-south mirror will be"

Section 5

Pg 11, Line 56: "The meteorology at each target was based on forecasts from the European Centre for Medium-range Weather Forecasts (ECMWF), interpolated to the time and location of each observation."

What time of year? What year? Nine pages back, in the introduction, we have learned that these are times near solstices and equinoxes, but that is all we know.

Pg 11, Line 60 (and pg 12 line 100): "Calipso" CALIPSO should be in capital letters. CALIPSO is an acronym for "Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations."

Pg 12, Line 85: "Generally in simulations of this type, random noise would be added to the unpolarised intensity in accordance with the noise model for geoCARB, and the resulting signal would be regarded as a measurement (or measured spectrum). However, because the focus of this study is the bias caused by polarisation, random noise was not added."

This choice was somewhat surprising. It would be more realistic to apply the same random noise to both experiments 1 and 2. The absence of realistic noise, combined with the use of the same forward model in the simulator and retrieval algorithm (which only differs in its treatment of the surface) will produce "optimistic" results. What is the effect of adding realistic noise on the primary results of the paper?

Section 6:

Pg 12, Line 95: "In contrast to the measured spectra, which were computed using polarising surfaces with directional reflectance, the modelled spectra assumed that the surfaces were non-polarising and Lambertian, with albedo varying linearly with wavelength."

This statement raises several questions: First, these are not "measured spectra." They are "simulated measurements" (with no noise or calibration errors). Second, how non-Lambertian were the surfaces used here? How structured were the bidirectional reflection functions (BRF's)? We later learn that the typical degree of polarization is 2%. What was the largest degree of polarization? Finally, in the introduction, we find the statement: "Instead it assumes that the surface is non-polarising, but it generates polarising elements internally." Here, it indicates that the retrieval algorithm assumes that the surface is Lambertian and unpolarized. Does this mean that all "polarizing elements" are attributed to clouds and aerosols or added to the Rayleigh scattering?

Pg 12, Line 97: "Thus, while the modelled surface was based on reasonable prior information, it differed in detail from the measured surface."

What was the prior used for the surface? Most such models simply retrieve the surface

reflectance from the continuum, without an explicit prior.

Also, what was the prior used for CO_2, CH_4, and CO? What it the same as the answer, except for the small (3ppm, etc.) random perturbations, or was it substantially different?

Pg 12, line 98: "This difference ensured that simulation followed by retrieval was not a circular process, and in fact was open to the range of errors we expect with real data."

This approach will introduces a systematic bias, but does not provide any information about the effects of random errors, which may affect your results differently, depending on the specification of the prior.

Pg 12, Line 101 and 103 "…two types of aerosol plus water and ice clouds…"

Try: … two types of aerosol plus liquid water and ice clouds …

Pg 13, Line 26; "In a sense this experiment represents the worst case, because it assumes that no pre-flight radiometric and polarimetric calibration has been performed."

No "radiometric" calibration as well? This suggests that you simply scaled the observed continuum to the simulated continuum, which I don't believe was the case here. If your simulated measuremens assumed some conversion from volts to radiometric units (watts or photons/sec per square meter per steradian per micron), and assumed that the observed amplitudes scaled linearly with input radiance, you have assumed some radiometric calibration.

Pg 13, Line 31: While the "typical" degree of polarization is 2%, what is its distribution? Were there any very much larger or smaller values? Did they pass your post processing screens?

Pg 14, Line 59: "While the differences in the average biases shown in Table 2 appear small, they nevertheless are important, because even small biases on large spatial scales can lead to significant errors in surface fluxes of CO_2"

The mean bias and variance shown here is actually quite large for an experiment that uses "perfect" gas absorption coefficients, similar forward models in the simulator and retrieval algorithm and assumes no random noise. Could it be that biases introduced by these relatively weakly polarizing land surfaces are much smaller than those introduced by the simplified surface BRF or cloud/aerosol model? This seems to be reinforced in your Conclusion section (pg 15, line 73), where you state:

“The ability of the retrieval algorithm to predict the polarisation state is limited because internally it assumes that the surface is non-polarising and Lambertian and that aerosols and clouds are composed from fixed types whose scattering (and polarising) properties are assigned, fixed and usually inconsistent with the real atmosphere. This inability leads to an irreducible minimum error when the algorithm is applied to a realistic ensemble of surfaces and atmospheres.”

This leads us to wonder what would happen if random noise was added.

Pg 15, line 85; “However, generally they are small, though they remain significant for XCO2 .”

Do these biases vary systematically with airmass or latitude?

Pg 16, Line 92: “Thus, even in the presence of significant polarization at the entrance aperture,”

What is "significant polarization?’ The only number cited is 0.02. That is not very "significant". This may be "typical" for the land surfaces considered here, but biases associated with the degree of polarization would still be of great concern because they might indicate spurious sources and sinks.

Pg 16, Line 95: “Through radiometric and polarimetric calibration before launch using the procedure defined in this study, errors from polarised surfaces and clouds can be reduced to negligible levels. “

You might want to qualify this. This is true in the presence of the other simplifications in the current model, which yield relatively large biases. Would this still be true in the

presence of much smaller systematic biases in the retrieval algorithm’s forward model?

Interactive comment on Atmos. Meas. Tech. Discuss., 8, 8779, 2015.